Slide 1

Noise Spectral Concepts

In the same sense as signals, noise can be described in terms of a spectral representation. Because of the random nature of noise, it is usually described in terms of a *power spectrum*. Thermal noise has a constant value over a wide bandwidth and is often referred to as *white noise*. An Arbitrary noise source can be represented in terms of an *equivalent noise temperature*, which may or may not be related to the physical temperature. However, it is treated like a physical temperature in noise analysis.

Slide 2

Power Spectrum

The available power from a resistance is

$P_N = kTB$

A one-sided power density $S(f)$

may be defined as

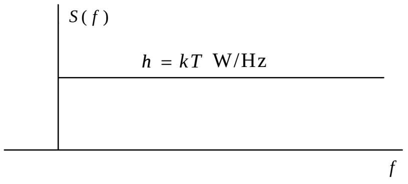
$S(f) = h = kT \quad \text{W/Hz}$

At $T = T_0 = 290\text{ K}$

$S(f) = h_0 = kT_0 = 4\times10^{-21} \quad \text{W/Hz}$

Slide 3

Form of Power Spectrum Over Wide Frequency Range on a One-Sided Basis



Slide 4

Input-Output Relationship for Power Spectrum

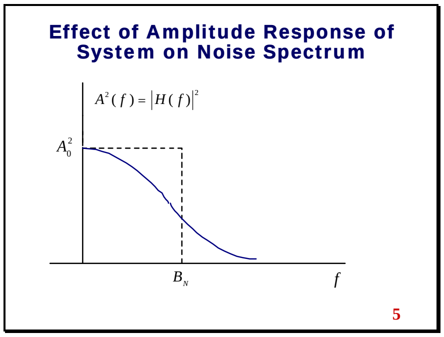
Let $S_i(f) =$ input power spectrum

$S_o(f) =$ output power spectrum

$G =$ matched power gain

$$S_o(f) = GS_i(f)$$

Slide 5



Effect of Amplitude Response of System on Noise Spectrum

Slide 6

Equivalent Noise Bandwidth

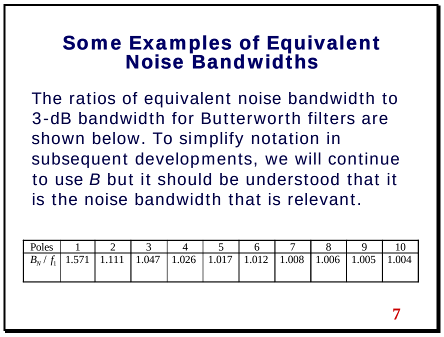
Let A_0^2 represent maximum value of amplitude-squared response.

$B_N =$ equivalent noise bandwidth

$$= \frac{1}{A_0^2}\int_0^{\infty} A^2(f)df$$

B_N is the value that should be used for noise analysis.

Slide 7

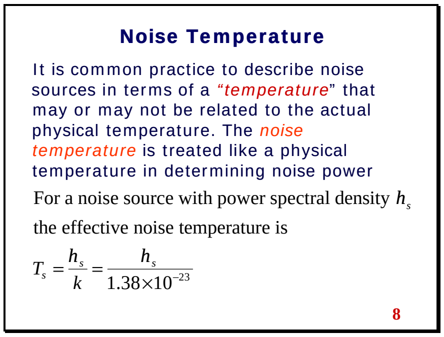


Some Examples of Equivalent Noise Bandwidths

The ratios of equivalent noise bandwidth to 3-dB bandwidth for Butterworth filters are shown below. To simplify notation in subsequent developments, we will continue to use *B* but it should be understood that it is the noise bandwidth that is relevant.

Poles	1	2	3	4	5	6	7	8	9	10
B_N / f_1	1.571	1.111	1.047	1.026	1.017	1.012	1.008	1.006	1.005	1.004

Slide 8



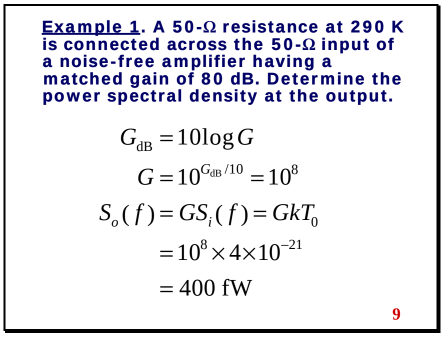
Noise Temperature

It is common practice to describe noise sources in terms of a “*temperature*” that may or may not be related to the actual physical temperature. The *noise temperature* is treated like a physical temperature in determining noise power

For a noise source with power spectral density h_s the effective noise temperature is

$$T_s = \frac{h_s}{k} = \frac{h_s}{1.38\times10^{-23}}$$

Slide 9



Example 1. A 50-Ω resistance at 290 K is connected across the 50-Ω input of a noise-free amplifier having a matched gain of 80 dB. Determine the power spectral density at the output.

$$G_{\mathrm{dB}} = 10\log G$$

$$G = 10^{G_{\mathrm{dB}}/10} = 10^8$$

$$S_o(f) = GS_i(f) = GkT_0$$

$$= 10^8 \times 4\times10^{-21}$$

$$= 400 \text{ fW}$$

Slide 10

<u>Example 2</u>. A noise generator produces white noise with a power spectral density of 6x10^{-3} W/Hz Determine equivalent noise temperature.

$$T_s = \frac{h_s}{k} = \frac{6\times10^{-18}}{1.38\times10^{-23}} = 434{,}800\ \text{K}$$

This is obviously not a

real physical temperature!

Slide 11

<u>Example 3</u>. The noise generator of Example 2 is connected across the input of a matched noise-free amplifier having a flat gain of 43 dB. Determine output power spectral density.

$$G = 10^{43/10} = 20\times10^{3}$$

$$\begin{aligned} S_o(f) &= GS_i(f) = 20\times10^{3}\times6\times10^{-3} \\ &= 120\ \text{fW/Hz} \\ &= h_o \end{aligned}$$

Slide 12

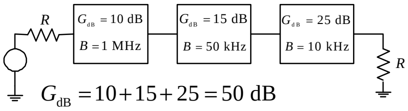
<u>Example 4</u>. For the system of Examples 2 and 3, determine the output power if the equivalent noise bandwidth is 12 MHz.

$$N_o = h_o B = 120\times10^{-15}\times12\times10^{6}$$

$$= 1.44\times10^{-6}\ \ \text{W} = 1.44\ m\text{W}$$

Slide 13

<u>Example 5</u>. Determine output noise of matched system below if input source has density of 1 pW/Hz and internal noise is negligible.



$$G_{\mathrm{dB}} = 10 + 15 + 25 = 50\ \mathrm{dB}$$

The noise bandwidth is 10 kHz.

$$N_o = h_i G B = 10^5 \times 10^{-12} \times 10^4 = 1\ \mathrm{mW}$$

Slide 14

Summary

- Noise may be described by a power spectral density function.
- For white noise, the power spectral density function is a constant.
- The output noise power density is the input noise power density times the amplitude response squared.
- A noise source may be represented in terms of a *noise temperature*.
- The equivalent noise bandwidth is the value used for noise power computations.